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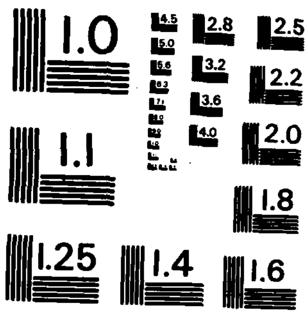

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report addresses the reliability prediction conducted on the two Navy owned and operated heat recovery incinerator systems. The prediction was based on a part counts methods and the original designs of the two HRI systems. Based on this prediction, long term data collected at Mayport and Jacksonville HRI systems and mission requirements, testing procedures for		

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HRI systems have been identified. Included in this report is a failure modes and effects analysis conducted at these HRIs.

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1.0 INTRODUCTION

This document contains the results of the reliability engineering analysis performed on the two Heat Recovery Incinerator (HRI) installations located at Naval Station (NS) Mayport and Naval Air Station (NAS) Jacksonville. Functional descriptions, reliablity models, reliability predictions, and Failure Modes and Effects Analysis (FMEA) are included. Navy Civil Engineering Laboratory (NCEL), Port Hueneme, California has conducted long- and short-term testing under the cognizance of Naval Facilities Engineering Command (NAVFAC-ENGCOM) to collect HRI reliability and maintainability, thermal efficiency, cost effectiveness, and solid waste characteristics data. The results of this reliability engineering analysis will be combined with the test findings as part of the overall HRI project planning.

The functional block diagram with supporting description provides the basis for all subsequent reliability analysis. The reliability model (i.e., block diagram) and FMEA are based directly on the functional flow diagram, while the reliability prediction is based on total equipment configuration but includes duty cycle of the various equipment.

The system reliability models (block diagrams) in this report provide the first look at the relative complexities of the two HRI plants with respect to reliability. Together with the part count prediction, this information will provide an estimate (on a gross order of magnitude) of the inherent reliability of each HRI. The results of the reliability prediction and FMEA and the reliability model help to identify design reliability deficiencies, compare the two facilities and alternate designs, and establish procurement criteria to enhance the reliability of future Naval HRI installations.

2.0 SCOPE

Development of the information contained in this report required a thorough understanding of HRI operations and intimate familiarization with HRI equipment. This was accomplished through constant interface with NCEL project engineers and discussions with HRI personnel during a four-day site visit. Much of the technical information was gleaned from the operations and maintenance manuals for each installation. Thus, most of the descriptions of a technical nature are based upon the original equipment configurations.

2.1 Reference Documents

The following documents were used in acquiring a functional and operational knowledge of the HRI installations at NS Mayport and NAS Jacksonville.

(1) Operation and Maintenance Manual, Refuse Incinerator Mayport Naval Station.

(2) Operations and Maintenance Manual for Heat Recovery Incinerator Facility, Building 952, NAS Jacksonville, Florida, Vols. I and II, April, 1980.

(3) Reliability, Availability, and Maintainability Project Plan, Heat Recovery Incinerator, VSE Corporation, Oxnard, California, April 1982.

(4) Long-Term Evaluation, Heat Recovery Incinerator System, Mayport, VSE Corporation, Oxnard, California, April 1982.

(5) Heat Recovery Incinerator Master Test Plan, Naval Civil Engineering Laboratory, December 1981.

(6) Operating Case History of the NAS Jacksonville Heat Recovery Incinerator Facility, July 1979 through June 1981, Civil Engineering Laboratory, Port Hueneme, California, July 1981.

(7) Test and Evaluation of the Heat Recovery Incinerator Systems at Naval Station, Mayport, Florida, CR 81.012, Civil Engineerng Laboratory, Port Hueneme, California, May 1981.

(8) Memorandum of Procedure for FY-81 Evaluation of NS Mayport HRI for Reliability and Maintainability, Naval Facilities Engineering Command, September 1980.

(9) Procedure for Reliability and Maintainability Evaluation of the NAS Jacksonville Heat Recovery Incinerators, Naval Civil Engineering Laboratory, Port Hueneme, California.

The following documents were used to provide the methods used in the Reliability analysis:

(1) MIL-HDBK-217C, Reliability Predictions

(2) MIL-STD-1629, Failure Modes and Effects Analysis

(3) RADC-LC-78-2, Storage Reliability Defense Technical Information Center

(4) Reliability Engineering, ARINC Research Corporation, 1964

(5) Reliability Technology, Greene A. E., and Bourne A. J., 1972

(6) MIL-STD-781C, Reliabilty Design Qualifications and Production Acceptance Tests: Exponential Distribution

(7) Reliability and Maintainability Technical Seminar, Project Engineer Guide, VSE Corporation (Oxnard), May 1981

3.0 SUMMARY

The following is a summary of the reliability parameters and test requirements for the HRI installations at NS Mayport and NAS Jacksonville.

A parts count reliability prediction based upon equipment identified in HRI operation and maintenance manuals estimated Mean-Time-Between-Failure (MTBF) values of 457 and 155 hours for NS Mayport and NAS Jacksonville, respectively. Based upon this prediction, the NS Mayport HRI can be expected to experience 14 failures and NAS Jacksonville HRI 27 failures in a calendar year. These failures will prevent solid waste incineration and steam production. The NAS Jacksonville HRI, with the network of front-end processing equipment, is more complex than the NS Mayport installation and will experience more failures.

A Failure Mode and Effect Analysis (FMEA) focusing on initial indenture equipment was performed for each installation. Results of this analysis indicated that only those equipment which provide feedwater to the boilers (deaerator, boiler feed pumps) and the ash removal conveyor can effect critical modes of failure (i.e., unable to produce steam from solid waste) at NAS Jacksonville. This is due in part to the ability to direct feed the incinerators by hand; thereby bypassing all front-end processing equipment. The standby incinerator/boiler capability also minimizes the impact of all incinerator or boiler failures. In contrast, failure of any major equipment assembly (i.e., overhead crane, incinerator, ash conveyor, boiler, ID fan, and feedwater systems) would effect a critical failure at the NS Mayport facility.

Test requirements to assure desired HRI system reliability (MTBF) were determined. For 80 percent confidence that the true MTBF of any HRI system is at least 538 hours, the system must test for 866 hours with zero or one failure or 1611 hours with two failures. Requirements for 90 percent confidence are appreciably high[illegible]d [illegible] provided in tabular format in section 9 of this report.

4.0 TECHNICAL APPROACH

The functional flow diagrams are based upon materials flow. No attempt is made here to portray mission essential equipment.

The reliability models (block diagrams) were developed using the guidance of MIL-HDBK-217C, Appendix A. These models are to the first indenture level and describe the relative complexities of the two HRI installations.

The functional output table and the operating characteristics for the equipment of each HRI were generated from existing operations and maintenance manuals. Noteworthy operational information is provided where no performance criteria were indicated.

The reliability prediction is based on the equipment that makes up each subsystem and the source of failure rates include MIL-HDBK-217C, Rome Air Development Center (RADC), and various reliability textbooks.

The FMEA was performed to the first indenture level and used the guidance of MIL-STD-1629.

5.0 HRI FUNCTIONAL DESCRIPTIONS

Functional descriptions and flow diagrams for the two HRI installations were developed from the respective operation and maintenance manuals. The following provides a description of the operation of the NS Mayport and NAS Jacksonville HRI installations.

5.1 Naval Station (NS) Mayport

The following is a description of the HRI installation at NS Mayport. A functional flow diagram in Figure 1 shows the major equipment that comprise the installation. There are three fundamental functions to this HRI installation. These are:

(1) Receipt and separation of solid waste (Blocks 1-5, 14)

(2) Incineration process (Blocks 6, 7, 15-18)

(3) Development of steam (Blocks 8-13, 19-25)

The numbers in parentheses refer to the corresponding block number in the functional flow diagram. Equipment controls (manual or automatic) are included with the individual equipment block.

Solid waste materials (1) are weighed and then delivered to the facility by truck and dumped onto the tipping floor (2). It is then hand sorted (3) to remove bulky or nonburnable items (14) to ensure smooth operation and avoid jamming of the ram feeder, stokers, and ash removal assemblies and minimize slag buildup in the incinerators. Once the refuse is sorted, a front-end loader (4) pushes the waste into the storage pit (5) for future use.

The waste materials are lifted by the overhead crane (6) from the pit, weighed (tons), and dropped into the incinerator hopper. A ram feeder pushes the solid waste into the primary furnace of the incinerator (7). The waste is then incinerated. The resulting ash products are removed from the bottom of

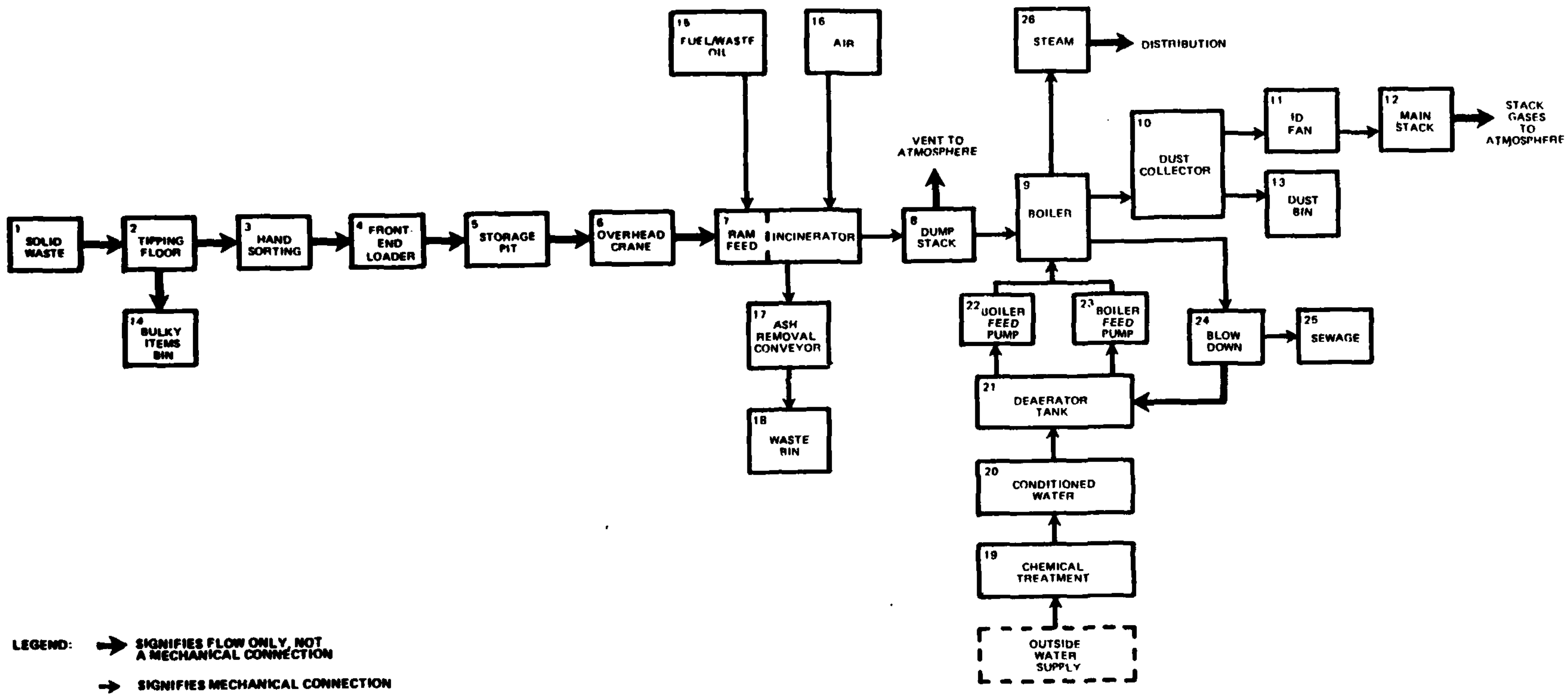

Figure 1. HRI Functional Flow Diagram–NS Mayport

the primary chamber by the stokers located on the bed of the incinerator. The ash is dropped into the quench tank for cooling, then removed by the ash removal conveyor (17) and deposited into the waste bin (18). The hot gases, liberated by the combustion of the refuse, are pulled through the secondary furnace and boiler by the ID fan (11).

The gases are ignited in the secondary chamber using waste oil (15) and oxygen (16) in order to obtain more heat and vent cleaner exhaust into the atmosphere. The hot gases continue through the fire tubes in the boiler (8) where the steam (9) is generated. The hot gases pass through a dust collector (10) and ID fan (11) and are sent up the main stack (12) and vented to the atmosphere.

The boiler feedwater is delivered to the facility from an outside source and is chemically treated (19). The conditioned water (20) is then stored in the deaerator tank (21) where it is preheated with steam from the boiler. Either boiler feed pump #1 or #2 (22 or 23) supplies conditioned preheated water to the boiler (18).

Table 1 provides operating characteristics for the equipment contained in the functional flow diagram.

Table 1. Mayport HRI Functional Output Table.

Equipment	Block Number	Function	Operational Characteristics
Overhead crane	6	Transports refuse from storage pit to incinerator	• 300 ft/min max trolley speed • 80 ft/min max hoist speed • 1-1/2 cubic yard bucket capacity

Table 1. Mayport HRI Functional Output Table (Continued).

Equipment	Block Number	Function	Operational Characteristics
Incinerator	7	Consumes combustible solid waste	• 20 cubic yard ram feeder capacity • 100K pounds of thrust in ram feeder • 2 tph feed rate • 10 gph oil burner capacity • 20 million Btu/hr design in primary combustion chamber • 50 gph afterburner capacity
Boiler	8	Fire-tube boiler produces steam	• 10,500 lbs/hr rated steam output • 290 lb/in^2 max water pressure • 1600°F entrance gas temp. • 500°F exit gas temp.
Dust collector	10	Removes fine particles and particulates	• 40 collector elements
ID fan	11	Provides draft for incinerator and hot gas for boiler	• 1355 rpm at 500°F
Main stack	12	Vents gases to atmosphere	• 75 feet high
Dust bin	13	Collects particles from dust collector	• 3 cubic yard containers (2)
Air	16	Supplies air to the incinerator	• 75 hp motor (1770 rpm) for primary and secondary combustion • 10 hp motor (1770 rpm) for stoker

Table 1. Mayport HRI Functional Output Table (Continued).

Equipment	Block Number	Function	Operational Characteristics
Ash removal conveyor	17	Transports ash from incinerator to waste bin	• 70 cubic feet capacity for water tank • 7.5 hp motor
Boiler feed pumps	19/ 20	Supplies boiler with treated water from deaerating tank	• 30 hp motor • 40 gpm (3550 rpm) for pumps
Deaerating tank	21	Removes air from water, preheats water for boilers, and acts as a surge tank	• 200°F preheat temp.

5.2 Naval Air Station (NAS) Jacksonville

The following is a description of the HRI installation at NAS Jacksonville. A functional flow diagram in Figure 2 shows the major equipment that comprise the installation. There are four fundamental functions to this HRI installation. These are:

(1) Receipt and separation of solid waste (Blocks 1-5 and 22)

(2) Processing train (Blocks 6-12, 23-25, 26-34)

(3) Incineration process (Blocks 13-18, 36-39)

(4) Development of steam (Blocks 19-21, 40-47)

The numbers in parentheses refers to the block number in the functional flow diagram. Equipment controls (manual or automatic) are included within the block depicting the equipment.

Solid waste materials (1) are delivered to the HRI facility by truck, are then weighed and dumped onto the tipping floor (2). The material is then hand sorted (3) such that crushable items are located in the vicinity of the flail

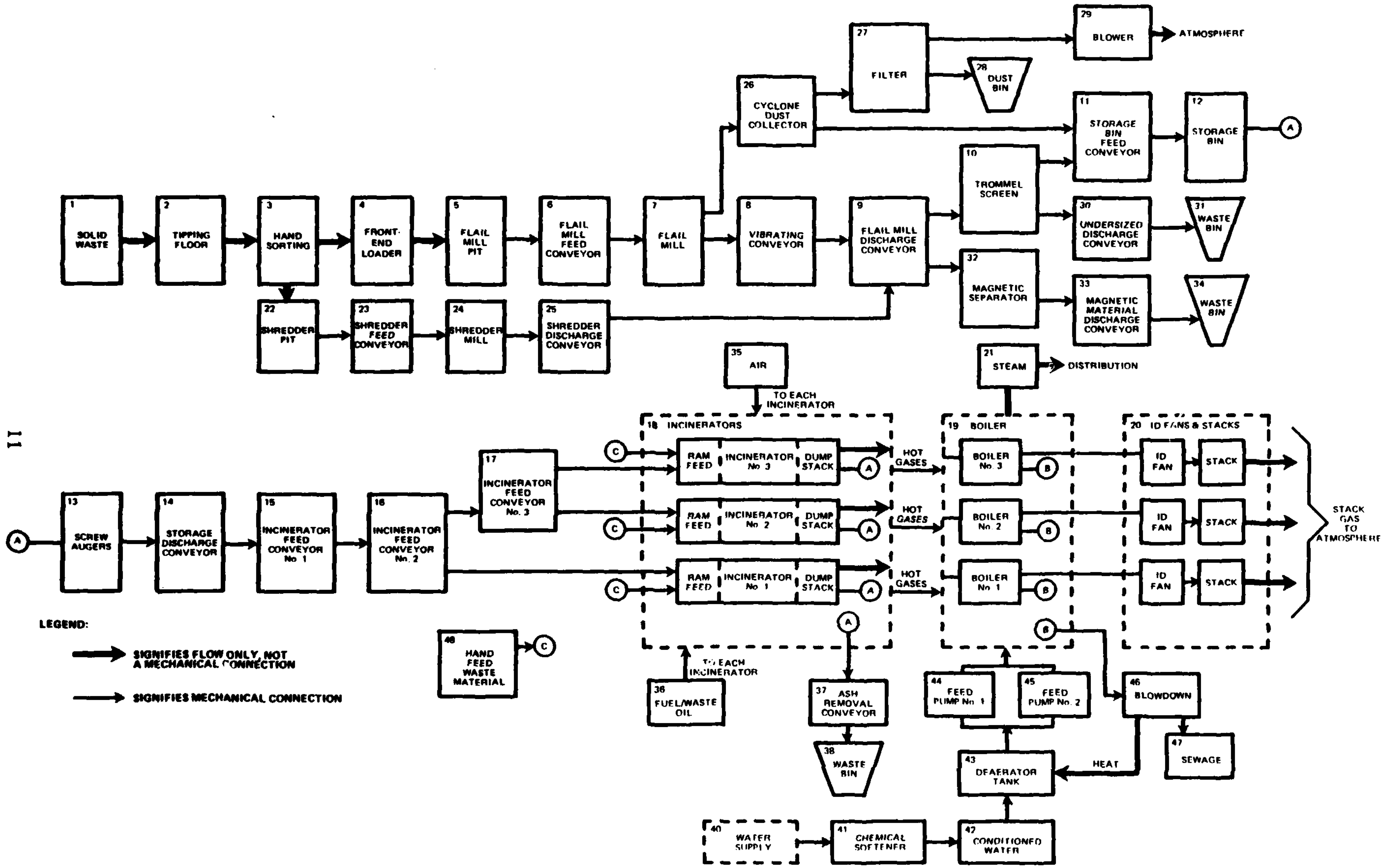

Figure 2. HRI Functional Flow Diagram--NAS Jacksonville

mill pit (5) and the material requiring shredding is placed near the shredder pit (22). Those items that cannot be processed are placed in waste bins.

A front-end loader (4) operator and another individual using a pitch fork are required for sorting and feeding the flail mill pit (5). The solid waste material is then moved by the feed conveyor (6) to the flail mill (7), where it is reduced to a particle size of 8 to 12 inches. The shredded waste material from the flail mill drops to a vibrating conveyor (8) that is used to provide an even feed to the flail mill discharge conveyor (9) and then to the trommel screen (10). A magnetic separator (32), with associated discharge conveyor (33) and waste bin (34), is used to pick up magnetic materials from the discharge end of the discharge conveyor (9) and deposit the material outside the building.

The trommel screen (10) removes undersized items (glass, ceramic, and metallic particles) not extracted by the magnetic separator before the waste material is placed on the storage bin feed conveyor (11) and into the storage bin (12). An undersized discharge conveyor (30) transfers the undersized items to the waste bin (34) outside the building. The air classification system (26-29) takes its suction from the flail mill discharge area to minimize airborne dust particles from the flail mill rotors. Dust is separated from the heavier particles in the cyclone separator (26), filtered (27), bagged, (28) and vented (29) to the atmosphere. The heavier particles drop out of the cyclone dust collector onto the storage bin feed conveyor.

A shredder mill (23) which is used to shred pallets, tires, wood, and solid waste to 12-inch size is fed from the shredder feed conveyor (22). The discharge conveyor (24) transfers the shredded material to the flail mill discharge conveyor (9) where it follows the same path as previously described.

The processed waste material in the storage bin (12) is delivered to the storage bin discharge conveyor (14) by means of two augers (13) located on the floor of the storage bin. This conveyor then delivers the waste material to incinerator feed conveyor #1 (15), which in turn feeds incinerator feed conveyor #2 (16), which in turn feeds incinerator feed conveyor #3 (17). Incinerator feed conveyors #2 and #3 are reversible. In order to feed incinerator #1, feed conveyor #2 moves in the reverse direction. In order to feed incinerator #2, feed conveyor #2 moves forward and feed conveyor #3 moves in reverse. In order to feed incinerator #3, both feed conveyors #2 and #3 move forward.

Upon delivery to each of the incinerators (18), the processed waste material is ram fed to the primary chamber and incinerated by combining it with oxygen (35) and small amounts of fuel/waste oil (36). The hot gases are pulled through to the secondary chamber by the induced draft fans (20). Here they are reignited to increase heat, complete combustion, and vent cleaner exhaust to the atmosphere. The waste residue is pushed from the primary chamber by the stoker grates into the quench tank for cooling and removed via the ash removal conveyor (37) to the waste bin (38).

The hot gases from the secondary chamber heat the water in the water-tube boilers (19) to produce steam (21). The hot gases then exit out each main stack (20) to the atmosphere. A dump stack is associated with each incinerator.

The boiler feedwater is delivered to the facility from an outside source and is chemically treated (41). The conditioned water (42) is then stored in the deaerator tank (43) where it is preheated with steam from the boiler. Either boiler feed pump #1 or #2 (44 or 45) supplies conditioned preheated water to the boilers (19).

The following table provides operating characteristics for the equipment contained in the functional flow diagram.

Table 2. Jacksonville HRI Functional Output Table.

Equipment	Block Number	Function	Operational Characteristics
Flail mill feed conveyor	6	Provides solid waste to flail mill	• 5 hp induction motor • 2.7-3.0 tph capacity (operating history)
Flail mill	7	Reduction of solid waste to 8- to 12-inch size	• 100 hp motors (2) • 10 tph capacity (design) • 2.7-3.0 tph capacity (operating history)
Vibrating conveyor	8	Absorbs shock from flail mill waste and delivers an even flow to the discharge conveyor	• 3 hp motor (430 rpm) • 4.5 lb/ft^3 at 5 tph (design) • 2.7-3.0 tph capacity (operating history)
Flail mill discharge conveyor	9	Carries flail mill and secondary shredder discharge materials to trommel screen	• 3 hp motor (1750 rpm) • 2.7-3.0 tph capacity (operating history) • 250 ft/min speed
Trommel screen	10	Removes glass, ceramic, and metallic particles not removed by the magnetic separator	• 15 hp motor • Screen rotates at 12 rpm • 2.8-3.0 tph capacity (operating history)
Storage bin feed conveyor	11	Transports waste from the trommel screen and cyclone to the storage bin	• 7-1/2 hp motor (1750 rpm) • 3 tph capacity (operating history)

Table 2. Jacksonville HRI Functional Output Table (Continued).

Equipment	Block Number	Function	Operational Characteristics
Storage bin	12	Acts as a surge bin to compensate in differences in front end processing train rate and incinerator burn rate	• 29 tons at 7 lbs/ft^3 capacity in bin • 3/4 hp DC motor for traverse drive carriage
Screw augers	13	Provides for movement of waste in storage bin	• 25 hp AC motor for screw drive carriage
Storage bin discharge conveyor	14	Receives storage bin refuse and feeds incinerator conveyor #1	• 5 hp motor • 3 tph capacity (operating history)
Incinerator feed conveyor #1	15	Receives refuse from the storage bin discharge conveyor and feeds incinerator feed conveyor #2	• 5 hp motor (1750 rpm) • 3 tph capacity (operating history)
Incinerator feed conveyor #2	16	Receives refuse from the incinerator feed conveyor #1 and feeds incinerator #1 or incinerator feed conveyor #3	• 3 hp motor (1750 rpm) • 3 tph capacity (operating history)
Incinerator feed conveyor #3	17	Receives refuse from the incinerator feed conveyor #2 and feeds incinerators #2 and #3	• 2 hp motor (1750 rpm) • 3 tph capacity (operating history)
Incinerators	18	Consumes combustible solid waste	• 24 tons per-day burning capacity • 1.0 million Btu/hr capacity of primary burners • 1.54 million Btu/hr capacity of secondary main burner

Table 2. Jacksonville HRI Functional Output Table (Continued).

Equipment	Block Number	Function	Operational Characteristics
Incinerators (continued)	18		• 0.84 million Btu/hr capacity of secondary pilot burner • 3 cubic yards ram loader capacity • 10 hp motor drives loader
Boilers	19	Water-tube boiler	• 125 psig produced saturated steam pressure • 150 psig design pressure rating • 6,280 lb/hr max steam production • 6.28 million Btu/hr heat transferred to water side • 17,000 lb/hr of flue gas at 1800°F received on gas side • 500°F on water side • 1/8 hp motor for rotary soot blowers
ID fans	20	Pulls flue gas through the boiler and drives gas out the main stack	• 30 hp motor
Shredder feed conveyor	23	Transports objects to inlet of shredder	• 5 hp induction motor • 1 TPH capacity (operating history)
Industrial shredder	24	Reduces pallets, tires, or solid waste to 12-inch size	• 23 hp motors (2) • 60 rpm and 40 rpm blade velocity

Table 2. Jacksonville HRI Functional Output Table (Continued).

Equipment	Block Number	Function	Operational Characteristics
Industrial shredder (continued)	24		• 90-120 pallets/hr capacity • 350 car tires/hr capacity • 150 truck tires/hr capacity • 5 tph of solid waste capacity • 1 tph capacity (est) (operating history)
Shredder discharge conveyor	25	Transports waste from shredder to flail mill discharge conveyor	• 5 hp motor (1750 rpm)
Cyclone dust collector	26	Removes light fraction of the waste stream	• 1.5-inch WG pressure drop • 4600 cfm air volume
Dust bin	28	Collects light fraction of the waste stream	• 516 ft^3 volume
Blower	29	Exhausts air to atmosphere	• 4728 cfm air volume
Undersized discharge conveyor	30	Transports undersized particles from trommel screen to a waste bin	• 3/4 hp motor
Magnetic separator	32	Removes ferrous metals from waste stream	• 10 tph capacity • 4500 watt rectifier for power (460 volt, 3 phase 60 hertz input; 115 volt, dc output) • 5 hp motor
Ferrous metals discharge conveyor	33	Transports metals from magnetic separator to a waste bin	• 1/2 hp motor

Table 2. Jacksonville HRI Functional Output Table (Continued).

Equipment	Block Number	Function	Operational Characteristics
Air	35	Supplies air to the incinerators	• 7 1/2 hp motor • 6000 cfm capacity
Fuel and waste oil	36	Supplies fuel to the incinerators	• 7.5 gallons #2 fuel oil/ton dry waste per day maximum • 1/3 hp motor for oil and air
Ash removal conveyor	37	Transports ash from incinerator to a waste bin	• 3 hp electric motor
Boiler feed pumps	41/42	Supply hot water from deaerator to boiler	• 45 gallons/min • 375 foot head • 20 hp electric motors (one each) • 125 psig water to boilers
Deaerator	43	Removes air from water, preheats water for boilers, and acts as a surge tank	• 92 ft^3 volume • 50 psig design pressure • 2-15 psig operating pressure • 20,000 lbs/hr capacity • 0.005 ml/liter oxygen maximum
Blowdown	46	Removes boiler water with high dissolved solids content and recovers the heat	• 2.6 ft^3 volume • 150 psig design pressure • 225 psig test pressure

6.0 HRI RELIABILITY BLOCK DIAGRAM

The HRI reliability block diagrams (i.e., model) discussed in this section are concerned with the relationship between the various equipment assemblies shown in Figures 1 and 2 and their effect on the performance of the HRI as related to the definitions of reliability. This relationship depends upon two conditions: first, the output or performance of an individual component, and second, the functional interrelationship of the components which together form the HRI installation. System reliability is defined as the probability of performing a specific function or mission under specified conditions for a specified time. The reliability block diagram shows the physical relationships of the various equipment and components that are required for mission success. It provides the series and parallel paths depicting the equipment required for success.

A thorough understanding of HRI intended use, performance parameters, and functional and physical boundaries is prerequisite to development of the system reliability model. Supporting systems that are required for the HRI to operate, but are not part of the HRI, are omitted from the model.

The reliability models in this report show all series and parallel paths at the initial indenture level. The initial indenture level is the first tier of equipment below the HRI installation. A path is a physical means for accomplishing a given task. A series path indicates that all the equipment in that path are necessary to perform a function. A parallel path indicates there are alternate methods to perform the same function. An example of a parallel path is in the NS Mayport HRI installation that has two feed water pumps to supply conditioned water to the boiler. Since either pump has the capacity to supply adequate water to the boiler, either can be used.

Finally, both HRI systems have two intended functions. The primary mission is to incinerate base-generated solid waste to reduce landfill requirements and costs. Second is the reclamation of energy in the form of steam for use by Naval facilities and/or ships. For the purpose of reliability analysis, the HRI mission objective will be defined as the ability to "produce steam by way of solid waste incineration." Thus, both functions must be attainable for successful HRI operation.

6.1 NS Mayport.

The Mayport HRI reliability block diagram in Figure 3 is predicated on the following assumptions:

- Mission success is defined as the ability to produce steam by way of solid waste incineration. All HRI equipment necessary to perform this task is considered.
- Two tph incineration rate is designed into equipment and represents the major performance criteria.
- Failure of any equipment within a block results in failure of that block (assembly).
- Failure of any incinerator or boiler controls results in system failure.
- Assemblies in standby mode are treated as parallel.
- Only normal and automatic control procedures are considered.

The following narrative descriptions identify each equipment or subassembly considered essential to the successful operation of each block in the diagram.

1. Overhead Crane Assembly (Block 10)

The overhead crane provides the means by which the solid waste is transported from the storage pit to the incinerator hopper. This assembly includes a radio-controlled crane with clamshell bucket.

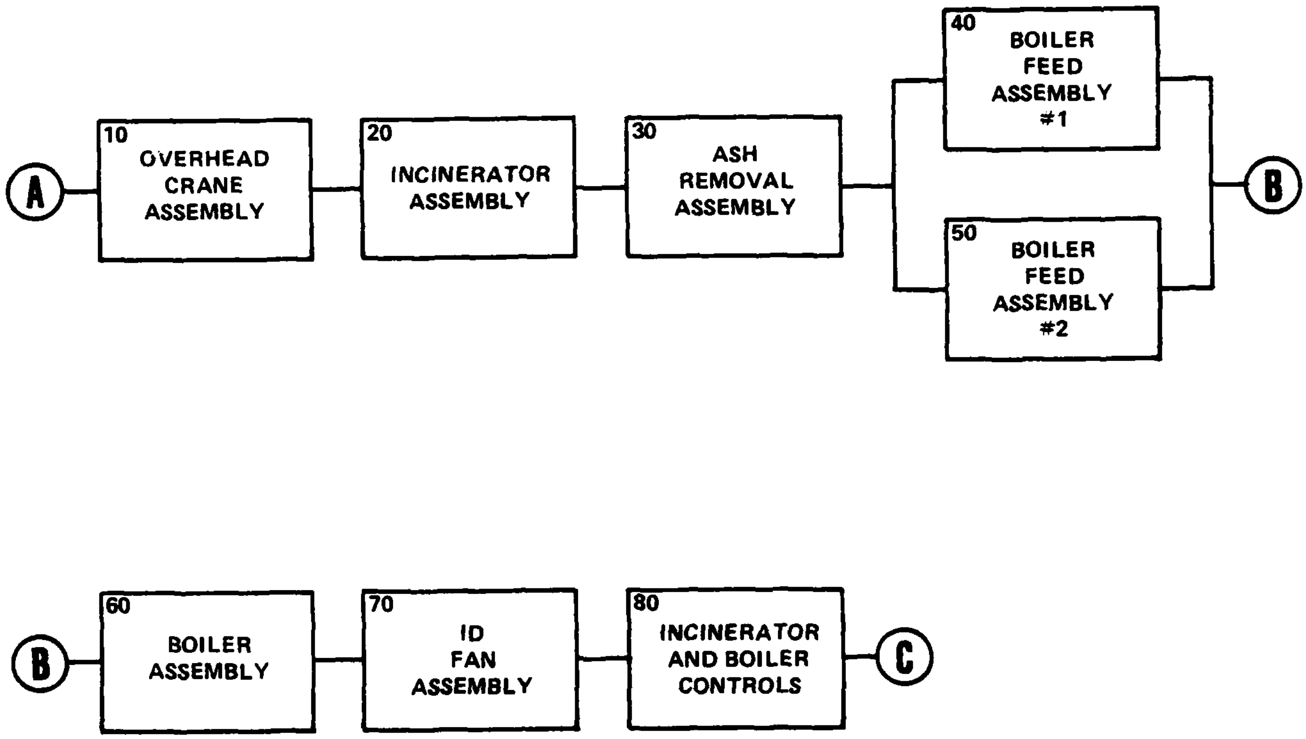

Figure 3. HRI Reliability Block Diagram–NS Mayport

2. Incinerator Assembly (Block 20)

The incinerator assembly provides for the incineration of solid waste to the highest extent practicable. This block consists of a two-stage incinerator with hydraulic power unit for both stoker and ram feed control. Also included are these support functions: waste and fuel oil pumps, controls and burners, temperature sensors and damper controls, and forced air for combustion and temperature control.

3. Ash Removal Assembly (Block 30)

This assembly provides for the removal of ash deposits delivered by the stokers. It consists of a motor-driven drag conveyor, low speed gear reducer, variable pitch pulley assembly, zero-speed switch which signals when the conveyor has stopped, and an automatic float control (valve).

4. Boiler Feed Assembly #1 (Block 40)

The boiler feed assembly operates in response to the boiler water level control to supply treated water from the deaerating tank to the boiler. This assembly consists of the deaerating tank and all associated controls and valves and boiler feed pump #1.

5. Boiler Feed Assembly #2 (Block 50)

This assembly serves as a backup to Block 40, with an automatic sequencing device providing for equal pump use time. It consists of equipment and components identical to that in Block 40, except it includes boiler feed pump #2.

6. Boiler Assembly (Block 60)

This assembly provides for heat transfer between feedwater supplied by pumps and hot gases from the incinerator. This block includes the fire-tube boiler, controls (steam and water) and valves, and blowdown equipment.

7. ID Fan Assembly (Block 70)

This assembly provides necessary draft to pull hot combustion gases from the incinerator to the boiler and up the main stack. This block includes the motor-driven ID fan.

8. Incinerator and Boiler Controls (Block 80)

This block consists of the various pushbutton switches, recorder-controllers, and the ram timer on the two control room consoles. Most controls are associated with incinerator functions. The controls for the fire-tube boiler are essentially provided for safety purposes rather than control of steam generation.

6.2 NAS Jacksonville.

The NAS Jacksonville HRI reliability block diagram shown in Figure 4 is predicated on the following assumptions.

- Mission success is defined as the ability to produce steam by way of solid waste incineration. All HRI eqipment necessary to perform this task is considered.
- Two tons per hour (tph) incineration rate is designed into equipment. Processing train duty cycle is one-third that of the heat transfer network (incinerator/boiler).
- Failure of any equipment in a block results in failure of that block (assembly).
- Failure of any processing equipment or incinerator controls results in system failure.
- Assemblies in standby mode are shown as parallel.
- Only normal and automatic control procedures are considered.

The following narrative descriptions identify each equipment or subassembly considered essential to the successful operation of each block in the diagram.

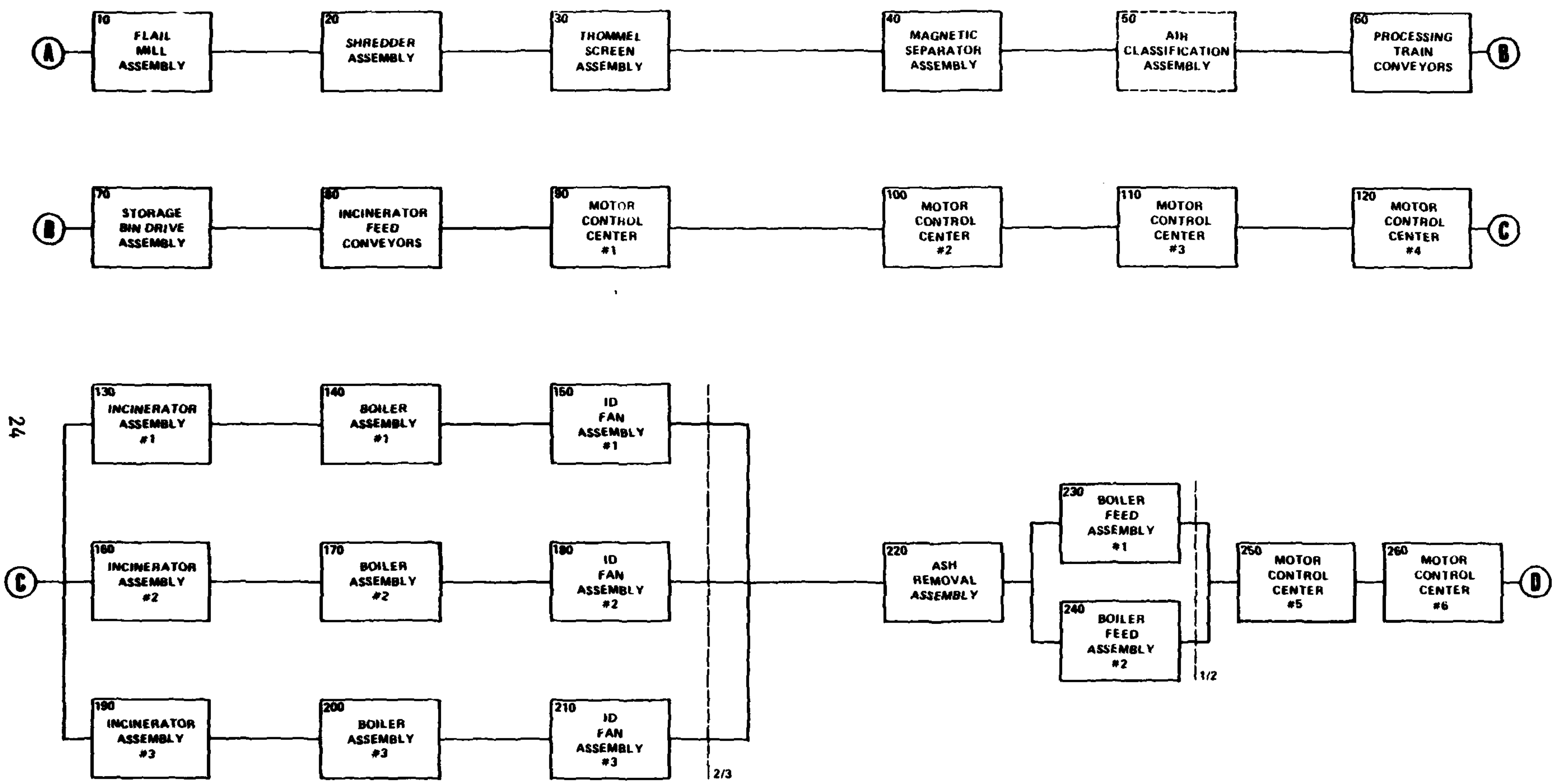

Figure 4. HRI Reliability Block Diagram–NAS Jacksonville

1. Flail Mill Assembly (Block 10)

The flail mill assembly uses two counter-rotating six-inch diameter rotors with flail tips to break up bulky objects before they are dropped onto the vibrating conveyor. This block consists of the flail mill feed conveyor, flail mill, vibrating conveyor, and discharge conveyor.

2. Shredder Assembly (Block 20)

Counter-rotating knives are used to reduce pallets, tires, and other solid waste to a maximum size of 12 inches. The shredder is operated intermittently when sufficient waste has accumulated. This block consists of the shredder feed and discharge conveyors and the shredder mill.

3. Trommel Screen Assembly (Block 30)

The trommel screen separates the small undersized particles (one-half inch or less) from the processing train that could potentially jam moving parts in the incinerators. This block includes the trommel screen and undersized discharge conveyor.

4. Magnetic Separator Assembly (Block 40)

The magnetic separator assembly consists of a high-powered electromagnet energized by a 4,500 watt rectifier (440 VAC to 115 VDC) and three permanent shakeout magnets. This block includes the magnet and the magnetic material discharge conveyor.

5. Air Classification Assembly (Block 50)

The air classification assembly removes potentially hazardous dust and airborne particulates from the flail mill. It also filters out the dust prior to ventilating this air to the atmosphere. This block includes the cyclone dust separator, dust collector, blower, and the explosion suppression system. It is not considered mission essential equipment in this evaluation.

6. Processing Train Conveyors (Block 60)

The processing conveyor assembly transports the waste material from the trommel screen discharge to the storage bin and from the discharge of the twin augers to the incinerator feed conveyors. This block includes the storage bin feed and discharge conveyors.

7. Storage Bin Drive Assembly (Block 70)

Twin screw augers are used to remove solid waste from the storage bins. This block includes the twin screw augers and associated drive mechanisms.

8. Incinerator Feed Conveyors Assembly (Block 80)

This assembly is made up of three separate conveyors to feed solid waste to the three incinerators. This block includes incinerator feed conveyors #1, #2, and #3.

9. Motor Control Center #1 (Block 90)

This control center provides for the manual control of the flail mill and the flail mill feed conveyor. This block contains all of the controls necessary to perform the above functions.

10. Motor Control Center #2 (Block 100)

This control center provides for the manual control of the vibrating conveyor, the shredder discharge conveyor, the flail mill discharge conveyor, the magnetic separator drive motor, the trommel screen drive motor, and the magnetic separator transformer/rectifier. This block center is made up of all panel controls necessary to operate the above equipment.

11. Motor Control Center #3 (Block 110)

This system provides for the manual control of the air classification system and the storage bin feed conveyor. This block consists of the panel controls necessary to operate the above functions.

12. Motor Control Center #4 (Block 120)

This control center provides for the manual control of the shredder and the shredder feed conveyor. This block consists of all of the necessary panel controls to operate the above equipment.

13. Incinerator Assembly (Blocks 130, 160, and 190)

This assembly provides for the incineration of the solid waste and the combustible gases liberated from the initial incineration of the solid waste products. This block includes a two-stage incinerator, ram feeder and associated hydraulics, four fuel oil burners, two stokers and their associated hydraulics, air blowers, temperature sensor, and the controls for the ram loader and oil burners.

14. Boiler Assembly (Blocks 140, 170, and 200)

The boilers provide for the transformation of heat to energy in the form of steam for use by ships at port. This block includes the water-tube boiler; the steam and mud drums; pressure, temperature, water level, and draft sensors; and pressure relief valves, dampers, and associated controls.

15. Induced Draft (ID) Fan Assembly (Blocks 150, 180, and 210)

Each ID fan assembly provides the suction needed to draw the hot gases from the incinerator to the boiler in order to accomplish the heat transfer process. At that point, it blows the stack gas out the main stack. Each block includes the drive motor and controls.

16. Ash Conveyor Assembly (Block 220)

This assembly provides for constant removal of ashes which have fallen into the quench tank from each of the three incinerators. This block consists of the ash removal conveyor.

17. <u>Boiler Feed Assembly No. 1 (Block 230)</u>

This assembly provides adequate water supply to the boiler. This block consists of the deaerating tank and all associated controls and valves and one of the two feed pumps.

18. <u>Boiler Feed Assembly No. 2 (Block 240)</u>

This assembly serves as a backup to Block 230. It consists of equipment and components identical to that in Block 230, except it includes boiler feed pump #2.

19. <u>Motor Control Center #5 (Block 250)</u>

This control center provides for the manual control of the storage bin screw auger drive, the storage bin travel drive, the storage bin discharge conveyor, and three incinerator feed conveyors. This block contains all of the panel controls necessary to operate the above equipment.

20. <u>Motor Control Center #6 (Block 260)</u>

This control center provides for the manual control of the wet ash conveyor and the two boiler feed pumps. This block contains all of the panel controls necessary to operate the above equipment.

7.0 RELIABILITY PREDICTION

This section contains the parts count reliability predictions for both NS Mayport and NAS Jacksonville HRI installations. This prediction method is most applicable during early design phases and to provide an estimate for systems assembled with off-the-shelf commercial equipment. The information needed to apply the method is (1) part types and quantities, (2) part quality information, and (3) equipment operating environment.

Part failure rate data was extracted from three primary sources: "Reliability Technology," A. E. Coreen and A. J. Bourne, Wiley-Interscience, 1972; "Nonelectronic Reliability Notebook," RADC-TR-75-22; and MIL-HDBK-217C. Individual part failure rates were summed to determine a base failure rate for each block in the reliability block diagram. A quality factor is applied to each subsystem base failure rate to adjust for part quality and environmental stress (i.e., heat, vibration).

HRI subsystem failure rates are summarized in the following sections. A detailed listing of part failure rates is contained in Appendix A.

7.1 NS Mayport

The predicted Mean Time Between Failure (MTBF) for NS Mayport HRI is 457 hours (2190 failures per million hours). This represents the average operating time until the occurrence of a failure for all equipment operating all of the time. The reduction of 2190 failures per million hours projects an estimated 14 failures per year. Duty cycles of equipment have been incorporated in this estimate. This means that on the average the HRI can be expected to experience 14 failures during a calendar year under conditions of ideal support (i.e., equipment burn-in, preventive maintenance, and operator training).

Table 3 provides a summary of the NS Mayport HRI subsystem failure rate data.

Table 3. Parts Count Prediction - NS Mayport

Subsystem	Failures per 10^6 hrs.
Overhead Crane	234
Incinerator Assembly	564
Ash Removal Assembly	519
Boiler Feed Assembly #1	38
Boiler Feed Assembly #2	38
Boiler Assembly	598
ID Fan Assembly	99
Incinerator and Boiler Controls	100
Totals	2190
System MTBF	457

7.2 NAS Jacksonville

The predicted MTBF for NAS Jacksonville HRI is 155 hours (6471 failures per million hours). Thus, on the average the HRI can be expected to operate for 155 hours before a failure occurs for all equipment operating all of the time. The NAS Jacksonville HRI is relatively more complex than NS Mayport since it employs a network of solid waste preprocessing equipment. This processing equipment is expected to operate for approximately eight hours during a typical day while the other equipment should perform for twenty-four hours per day. These duty-cycle considerations are included in the reduction of 6471 failures per million hours to an estimated 27 failures per year.

Table 4 provides a summary of the NAS Jacksonville HRI subsystem failure rate data.

Table 4. Parts Count Prediction - NAS Jacksonville

Subsystem	Failures per 10^6 hrs.
Flail Mill Assembly	514
Shredder Assembly	400
Trommel Screen Assembly	233
Magnetic Separator Assembly	243
Processing Train Conveyors	68
Storage Bin Drive Assembly	280
Incinerator Feed Conveyors	352
Incinerator Assembly #1	664
Incinerator Assembly #2	664
Incinerator Assembly #3	664
Boiler Assembly #1	472
Boiler Assembly #2	472
Boiler Assembly #3	472
ID Fan Assembly #1	112
ID Fan Assembly #2	112
ID Fan Assembly #3	112
Ash Removal Assembly	311
Boiler Feed Assembly #1	26
Boiler Feed Assembly #2	26
Motor Control Centers 1-6	274
Totals	6471
System MTBF	155

8.0 FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

An FMEA was performed on both HRI installations. The FMEA evaluates the reliability of the design by postulating probable failure symptoms (modes) and determining the resulting effects of that failure. In addition, the basic cause of each failure and the design recommendations to circumvent or mitigate each are provided.

MIL-STD-1629 provided the basic guidance for the performance of the FMEA.

A thorough understanding of the basic operation of each HRI is a prerequisite to conducting the system-level FMEA. The functional flow diagram and supporting system description in Section 4.0 provides the basis for the FMEA.

In performing the system-level FMEA and compiling the results on the attached worksheet, the following criteria were used. Each area discussed below refers to the identical column on the worksheet.

a. <u>Output Specification/Functional Description</u>

General subsystem requirements were used to provide the output specification/functional description for the HRI installation being analyzed.

b. <u>Failure Symptom</u>

A serial number is provided for identification of the failure symptom and possible cause. The numbers are assigned sequentially. The failure symptom description indicates the different ways in which each output specification or functional description deviates from the required performance.

c. <u>Possible Causes</u>

This is the possible cause associated with each postulated failure symptom identified in b above.

d. <u>Failure Detection Method</u>

The failure detection method is used to describe the features that are incorporated in the design through which occurrence of a failure mode is recognized. The word <u>none</u> indicates that there is no direct or indirect method of failure detection.

e. Effect of Failure

The effect of failure will be the consequences of each assumed failure symptom on the operation, function, and/or status of the system being analyzed. The effect of failure describes the results of the failure symptom on the system being evaluated.

f. Existing Compensating Provision

An existing compensation provision is an integral part of the design that either circumvents or mitigates the effect of the postulated failure. Compensating provisions include redundant items that allow continued and safe operation if one or more items fail, alternate modes of operation, and safety or relief devices.

g. Classification of Failure

The following classification of failures apply to the HRI installation.

(1) Level 1 Minor (negligible). Failure mode characterized by the following condition:

(a) The HRI installation is more difficult to operate.

(2) Level 2 Major (marginal). Failure mode characterized by the following condition:

(a) The normal operation of the HRI cannot be performed. (i.e, if the front-end processing equipment at NAS Jacksonville had a breakdown, the incinerators could be hand-fed and steam still generated.)

(3) Level 3 Critical. Failure mode characterized by the following condition:

(a) Unable to produce steam from solid waste.

h. Failure Probability

Failure probability is provided for each possible cause for all postulated, identified failure symptoms. Failures and probabilities are based on the complexity of the equipment, usage and application within the subsystem, and historical data. Generic terms such as very low, low, medium, and high will be used to describe each failure probability and will be established based on equipment complexity.

i. Remarks

Recommended improvements are provided to either reduce the classification of failure or provide optimum compensating provision or improve maintenance and operation procedures.

An FMEA has been performed on both HRI installations. The results of the FMEA are contained on the following worksheets.

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FMEA

FAILURE MODE AND EFFECT ANALYSIS

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1. OUTPUT SPECIFICATION FUNCTIONAL DESCRIPTION	2. FAILURE SYMPTOM SERIAL NUMBER	DESCRIPTION	3. POSSIBLE CAUSES	4. FAILURE DETECTION METHOD	5. EFFECT OF FAILURE	6. EXISTING COMPENSATING PROVISION	7. CLASS OF FAILURE	8. FAIL PROB	9. REMARKS
Provide presorted solid waste to incinerator.	001	Unable to provide presorted solid waste to incinerator.	Front end loader inoperable.	Direct observation. Loader does not operate.	Presorted waste material is not provided to incinerator.	Borrow a front end loader.	Minor	Low	Ensure there is a procedure to borrow a front end loader from another base activity.
			Overhead crane inoperable.	Direct observation. Crane does not respond to commands	Presorted waste material is not provided to incinerator.	None.	Critical	Medium	Controls are currently transmitted remotely by RF. A hard-wired system would greatly improve this operation.
Incinerate presorted solid waste.	002	Unable to incinerate presorted solid waste.	Ram feed inoperable.	Direct visual observation.	Unable to feed waste material to incinerator.	None.	Critical	Low	Ensure that the hydraulic power system is inspected and serviced periodically. Ensure that the hopper design is such to provide an even flow.
			Stoker feed inoperable.	Indirect: instruments show unusual readings. Ram feed operates sluggishly.	Waste material piles up in incinerator at input port.	None.	Critical	Very low	Provide for inspection and service of the stoker during shut down periods.

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Incinerate presorted solid waste (Cont'd).	002 (Cont'd)	Unable to incinerate presorted solid waste (Cont'd).	Loss of combustion air and/or fuel/waste oil.	Indirect. Instruments show drop in chamber temperature.	Presorted waste material does not incinerate.	None.	Critical	Very low	Ensure sizing of motors for fans and oil all sized adequately for maximum demand. Provide periodic inspection and cleaning of tuyeres and oil burners. Ensure design has more tuyeres than required.
			Ash removal conveyor inoperable.	Direct observation that conveyor is not moving.	Unburned waste material is not removed from Quench tank.	None.	Critical	Low	Provide a remote monitor indication at control panel that shows whether the conveyor is moving or not. Ensure that the conveyor is periodically inspected and serviced. Make replacement of shear pins easy to perform.
			I. D. fan inoperable.	Instruments Boiler temperature and pressure.	Waste material does not incinerate.	None.	Critical	Very low	Provide periodic inspection and service of the I. D. fan. Inspect and replace fan belts at frequent intervals.

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	SERIAL NUMBER	DESCRIPTION							
Produce steam from presorted, incinerated waste material.	003	Unable to produce steam from presorted incinerated waste material.	Boiler inoperable.	Instruments Boiler temperature or pressure.	No steam is produced.	None.	Critical	Low	Ensure that the boiler and associated attachments are periodically inspected and serviced.
			Lack of water caused by: 1. Both feed pumps inoperable; 2. Deaerator tank clogged.	Instruments Site gauge, Boiler temperature and/or pressure.	No steam is produced.	None.	Critical	Very low	Ensure that the power to both feed pumps is from different sources. Provide for remote indication at manned control station, which feed pump is operating, and water level in deaerating tank.
			Relief stack stuck open.	Instrument No steam recorded on flowmeter.	No steam is produced.	None.	Critical	Low	Ensure that the relief stack controls are periodically inspected and serviced.

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Provide crushed waste material to storage bin.	001	Unable to provide processed solid waste to storage bin.	Flail mill feed conveyor inoperable.	Direct observation; conveyor does not move.	Processed solid waste is not provided to storage bin.	Shredder	Major	Very low	Ensure that the motor driving the conveyor is sized properly for the intended loads and that waste cannot be jammed at the discharge side of the conveyor (i.e., between rollers and conveyor.
			Flail mill inoperable.	Visual and audible; no sound and waste is not torn.	Processed solid waste is not provided to storage bin.	Shredder	Major	Low	The flail mill should be inspected and adjusted periodically.
			Vibrating conveyor inoperable.	Direct observation; conveyor does not move.	Processed solid waste is not provided to storage bin.	Shredder	Major	Very low	Ensure that the motor driving the conveyor is sized properly for the intended loads and that waste cannot be jammed at the discharge side of the conveyor.
			Flail mill discharge conveyor inoperable.	Direct observation; conveyor does not move.	Processed and shredded solid wastes are not provided to storage bin.	Hand feed the incinerator.	Major	Very low	Ensure that the motor driving the conveyor is properly sized for the intended loads (i.e., both crushed and shredded). Bar at top of conveyor should be removed to avoid jams.

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Provide crushed waste material to storage bin.	001 (Cont'd)	Unable to provide processed solid waste to storage bin.	Trommel screen inoperable.	Direct observation; no solid waste being discharged.	Processed and shredded solid wastes are not provided to storage bin.	Hand feed the incinerator.	Major	Low to medium	Provide a new configuration trommel, one that does not jam easily. The trommel should be the opened-ended type so that the solid waste would drop out.
			Storage bin conveyor inoperable.	Direct observation; conveyor does not move.	Processed and shredded solid wastes are not provided to storage bin.	Hand feed the incinerator.	Major	Very low	Ensure that the motor driving the conveyor is properly sized for the intended loads. Service of motor is dangerous as it hangs over the storage bin. Motor should be relocated.
Provide shredded waste material to storage bin.	002	Unable to provide shredded solid waste to storage bin.	Shredder feed conveyor inoperable.	Direct observation; conveyor does not move.	Shredded solid waste is not provided to storage bin.	Hand feed the incinerator.	Major	Very low	Ensure that the motor driving the conveyor is properly sized for the loads.
			Shredder mill inoperable.	Direct observation; no discharge.	Shredded solid waste is not provided to storage bin.	Hand feed the incinerator.	Major	Low	The shredder mill should be inspected and adjusted on a scheduled basis.
			Shredder discharge conveyor inoperable.	Direct observation; conveyor does not move.	Shredder solid waste is not provided to storage bin.	H[illegible] feed the incinerator.	Major	Very low	Ensure that the motor driving the conveyor is properly sized for the intended load. Provide periodic inspection and service.

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Provide processed waste material from storage bin to the incinerator.	003	Unable to provide crushed and/or shredded solid wastes to the incinerator.	Screw auger inoperable.	Direct observation; augers do not move.	Crushed and/or shredded solid wastes are not provided to the incinerator.	Hand feed unprocessed waste material to the incinerator.	Major	Low	Ensure that the motor and chain drive are periodically inspected and that the chain is kept free of all waste to avoid jamming.
			Storage discharge conveyor inoperable.	Direct observation; conveyor does not move.	Crushed and/or shredded solid wastes are not provided to the incinerator.	Hand feed unprocessed waste material to the incinerator.	Major	Very low	Ensure sizing of the drive motor is adequate for the intended loads.
			Incinerator feed conveyor #1 inoperable.	Direct observation; conveyor does not move.	Crushed and/or shredded solid wastes are not provided to incinerators.	Hand feed unprocessed waste material to the incinerator.	Major	Very low	Ensure sizing of the drive motor is adequate for the intended loads and that the receiving end of the conveyor is not easily jammed by the discharge from the storage conveyor.
			Incinerator feed conveyor #2 inoperable.	Direct observation; conveyor does not move.	Crushed and/or shredded solid wastes are not provided to incinerators.	Hand feed unprocessed waste material to the incinerator.	Major	Very low	Ensure that the sizing of the motor is adequate for the intended loads and that service to the motor is performed easily and readily.

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Provide processed waste material from storage bin to the incinerator.	003 (Cont'd)	Unable to provide crushed and/or shredded solid wastes to the incinerator.	Incinerator feed conveyor #3 inoperable.	Direct observation; conveyor does not move.	Crushed and/or shredded solid wastes are not provided to incinerator #2 or #3.	Hand feed unprocessed waste material to the incinerator.	Major	Very low	Ensure that the sizing of the motor is adequate for the intended loads and that service to the motor is performed easily and readily.
			Ram feed #1 inoperable (jammed).	Direct observation; waste material does not feed to the incinerator.	Crushed and/or shredded solid wastes are not provided to incinerator #1.	Use incinerator #2 or #3.	Minor	Low	Ensure that the ram feed is periddically serviced and that the design and the shape of the ram minimize jams.
			Ram feed #2 inoperable (jammed).	Direct observation; waste material does not feed to incinerator.	Crushed and/or shredded solid wastes are not provided to incinerator #2.	Use incinerator #1 or #3.	Minor	Low	Ensure that the ram feed is periodically serviced and that the design and the shape of the ram minimize jams.
			Ram feed #3 inoperable (jammed).	Direct observation; waste material does not feed to incinerator.	Crushed and/or shredded solid wastes are not provided to incinerator #3.	Use incinerator #1 or #2.	Minor	Low	Ensure that the ram feed is periodically serviced and that the design and the shape of the ram minimize jams.

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Incinerate crushed and/or shredded solid wastes.	004	Unable to incinerate solid waste.	Ash removal conveyor inoperable.	Direct observation; conveyor does not move.	Solid waste does not incinerate.	None.	Critical	Low to medium.	Ensure that the sizing of the motor to drive the conveyor is sufficient to handle all three incinerators' loads. Consideration should be given to having an ash removal conveyor per incinerator.
			Incinerator #1 inoperable.	Instruments; low temperature.	Solid waste does not incinerate.	Use incinerator #2 or #3.	Major	Low	Provide periodic inspection and service of the incinerator.
			Incinerator #2 inoperable.	Instruments; low temperature.	Solid waste does not incinerate.	Use incinerator #1 or #3.	Major	Low	Provide periodic inspection and service of the incinerator.
			Incinerator #3 inoperable.	Instruments; low temperature.	Solid waste material does not incinerate.	Use incinerator #1 or #2.	Major	Low	Provide periodic inspection and service of the incinerator.
			Air supply insufficient and/or waste/fuel oil not available.	Instruments; low temperature. Air supply. No waste/fuel oil.	Solid waste material does not incinerate.	Use alternating incinerator.	Major	Low	Provide periodic service and inspection of the waste/fuel oil and air supply systems.

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Incinerate crushed and/or shredded solid wastes.	004 (Cont'd)	Unable to incinerate solid waste.	I. D. fan inoperable.	Instruments; boiler temperature and pressure.	Solid waste material does not incinerate.	Use alternating incinerator.	Major	Very low	Ensure that each I. D. fan is periodically serviced and inspected. Replace fan belts frequently.
Generate steam from solid waste.	005	Unable to generate steam from solid waste.	Lack of water caused by: 1. Boiler feed pumps inoperable; 2. Deaerator tank clogged.	Site gauge; boiler temperature increases rapidly.	Steam is not generated.	None.	Critical	Very low	Ensure that the power to the two pumps are from different sources. Provide periodic service and inspection of boiler feed pumps and deaerator tank. Provide remote indication at manned control station for boiler water level.
			Incinerator or boiler #1 inoperable.	Instrument; no steam recorded on flow meter.	Steam is not generated.	Use incinerator and boiler #2 or #3.	Major	Low	Ensure that the incinerator and associated boiler are inspected and serviced periodically.
			incinerator or boiler #2 inoperable.	Instrument; no steam recorded on flow meter.	Steam is not generated.	Use incinerator and boiler #1 or #3.	Major	Low	Ensure that the incinerator and associated boiler are inspected and serviced periodically.

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	SERIAL NUMBER	DESCRIPTION							
Generate steam from solid waste.	005 (Cont'd)	Unable to generate steam from solid waste.	Incinerator or boiler #3 inoperable.	Instrument; no steam recorded on flow meter.	Steam is not generated.	Use incinerator and boiler #1 or #2.	Major	Low	Ensure that the incinerator and associated boiler are inspected and serviced periodically.
			Relief stack #1, #2, or #3 stuck open.	Instrument; no steam recorded on flow meter. Direct; dirty gases venting to atmosphere.	Steam is not generated.	Use alternating boiler.	Major	Low	Ensure that the relief stack controls are periodically serviced and inspected.

9.0 RELIABILITY TEST REQUIREMENTS

In accordance with MIL-STD-781C, a fixed length test plan is recommended when it is necessary to ascertain an estimate of the true MTBF demonstrated by testing or when total test time must be known in advance. The purpose of this section is to establish general and specific test requirements to determine if HRI reliability requirements have been met.

9.1 Definitions

HRI reliability is defined as the probability, at a given confidence level, that the HRI will perform its intended functions without failure, during a specified mission time, when used as intended under specified operation environment conditions. For the purpose of system evaluation, a failure will be counted (chargeable) only if it: (1) results in the inability of the HRI to incinerate solid waste and produce steam using equipment standard operating procedures and (2) requires greater than one-half hour to restore system operation. The HRI mission duration is specified as 24 hours per day for 5 consecutive days (or 120 hours) with a 48-hour shutdown period for regularly scheduled preventive maintenance.

9.2 Specific Requirements

Reliability values of 0.90 have traditionally been desirable target values. These were predominantly associated with the tactical importance of the system. Experience with HRI operation scenario and an appreciation of the various nonstandard operating procedures (i.e., incinerator hand-feed, manual override controls) indicates that 0.80 reliability is more than acceptable for such systems.

The exponential equation for reliability (R) is expressed in equation 1.

$$R = e^{-t/MTBF} \tag{1}$$

(1)

where,

e = base of naperian log system (2.718)

t = specified mission time

MTBF = mean time between failures

Given a 0.80 reliability goal and a 120-hour mission time, the HRI MTBF requirement (goal) is set at 538 hours.

Application of the exponential failure law for determining the HRI MTBF goal is illustrated as follows:

$$R = e^{-t/MTBF} \tag{2}$$

$$\ln R = \ln e^{-t/MTBF}$$

$$\ln R = -t/MTBF$$

$$MTBF = -t/\ln R$$

$$MTBF = -120'-0.223$$

$$MTBF = 538.1 \text{ hours}$$

Test demonstration of the MTBF provided by equation 2 means that eight out of ten times (or 41 weeks per year) an initially operable HRI will operate successfully from startup Monday morning until shutdown Friday afternoon. Hence, 538 hours becomes the minimum acceptable (specified) MTBF for HRI systems. To minimize the probability of concluding from test data that the HRI true MTBF is at least 538 hours, when in fact it is less, 538 hours is set as the lower confidence limit MTBF. Table 5 provides statistical test requirements to demonstrate the specified MTBF with 90 and 80 percent confidence. It

is shown that a minimum of 867 hours of testing with zero or one failure is required to assure, with 80 percent confidence, that the true HRI MTBF will be at least 538 hours.

Table 5. Test Requirements for HRI Lower Confidence Limit MTBF of 538 Hours.

	90% Confidence			80% Confidence		
Total Failures	Demonstrated MTBF	Testing Hours	Min. Days	Demonstrated MTBF	Testing Hours	Min. Days
5	859.4	4,297	180	723.1	3,616	151
4	898.2	3,593	150	742.1	2,968	124
3	953.9	2,862	120	767.5	2,302	96
2	1,044.7	2,089	88	805.4	1,611	68
1	1,239.6	1,240	53	866.3	867	37
0	1,239.6	1,240	53	866.3	867	37

10.0 COMPARISON OF FY-81 DATA AND PREDICTED VALUES - NS MAYPORT

The long-term RAM evaluation conducted at NS Mayport reported a system MTBF of 126 hours. This value was based on data collected during fiscal year 1981 (FY-81) in which 27 failures were documented during 3400 hours of operation. A close inspection of the reported equipment failures reveals that certain FY-81 failures are not assessable to the HRI equipment (parts) used in the parts count prediction (Section 6). For example, the boiler hand hold plug, incinerator relief stack refractory and tuyeres, and ash conveyor flight bars are considered passive equipment not included in the prediction. In addition, jammed gears and chains off sprockets due to debris are not accounted for in the predictions. Removal of these failures from FY-81 data would increase the MTBF to approximately 200 hours. This is still below the predicted 457 hours MTBF provided in Section 6.

The predicted MTBF is applicable to systems having proven design, regular maintenance cycles, and ideal support environments. It is conceivable that some of the equipment modifications, part substitutions, and repair procedures during FY-81 have contributed to the relatively low MTBF. Conversely, a parts stress analysis evaluating the HRI design in detail might very well uncover some highly stressed components resulting in an MTBF approximating the FY-81 values. Finally, the parts count prediction may very well be a sound estimate of the true HRI reliability. Additional RAM evaluation data combined with FY-81 data may provide MTBF estimates which more closely approximate the predicted value.

APPENDIX A

PART FAILURE RATE DATA

APPENDIX A

Part Failure Rate Data - NS Mayport HRI

Subsystem	Base $F/10^6$ hrs	Adjustment Factor	Adjusted $F/10^6$ hrs	MTBF
CRANE	187.2	π = 1.25	234	4274
•3 hp motor	10.0			
•20 hp motor	10.0			
•battery	1.0			
•clutch assy	6.0			
•receiver board	20.0 est			
•springload	0.2			
•RF XMTR	140.0 est			
INCINERATOR	376.1	π = 1.50	564	1773
•10 hp motor	10.0			
•10 hp motor	10.0			
•20 hp motor	10.0			
•75 np motor	10.0			
•1 3/8 hp motor	10.0			
•1 3/8 hp motor	10.0			
•hydraulic power unit	44.2			
•ram timer	63.6			
•solenoid valve	30.0			
•check valves(2)	2.2			
•PR valves (2)	4.8			
•pumps (2)	7.0			
•thermocouples(2)	160.4			
•piping	0.7			
•solenoid valve	3.2			
ASH REMOVAL	207.4	π = 2.50	518.5	1929
•7.5 hp motor	95.9			
•sleeve bearing(3)	10.0			
•shafts(2)	0.4			
•pins	15.0			
•belt drive	40.0			
•pulley	5.5			
•float valve	30.0			
•coupling	10.6			

APPENDIX A (Continued)

Part Failure Rate Data - NS Mayport HRI

Subsystem	Base $F/10^6$ hrs	Adjustment Factor	Adjusted $F/10^6$ hrs	MTBF
BOILER FEED #1	37.7	π = 1.0	37.7	26525
•feed pump	10.5			
•check valve	2.7			
•gate valves(2)	17.9			
•D.A. tank	3.0			
•heat exchanger	3.6			
BOILER FEED #2	37.7	π = 1.0	37.7	26525
•feed pump	10.5			
•check valve	2.7			
•gate valves(2)	17.9			
•D.A. tank	3.0			
•heat exchanger	3.6			
BOILER ASSEMBLY	478.4	π = 1.25	598	1672
•water level control	30.0			
•thermocouple	80.2			
•gate valves(9)	40.2			
•blowdown valve	15.0			
•piping	5.0			
•tank	263.0			
•tubes	40.0			
ID FAN ASSEMBLY	49.7	π = 2.0	99.4	10060
•axial fan	3.7			
•current relay	20.0			
•motor	10.0			
•damper	6.0			
•motor	10.0			
INCINERATOR/ BOILER CONTROLS	80.3	π = 1.25	100.4	9960
•PB switches(10)	5.3			
•recorder(3)	75.0			

APPENDIX A (Continued)

Part Failure Rate Data - NAS Jacksonville HRI

Subsystem	Base $F/10^6$ hrs	Adjustment Factor	Adjusted $F/10^6$ hrs	MTBF
FLAIL MILL ASSEMBLY	257.0	π = 2.0	514	1946
•5 hp motor	11.0			
•coupling	10.6			
•gear reduction(3)	3.0			
•shafts(2)	4.4			
•100 hp motor(2)	20.0			
•bearings	5.0			
•gears(2)	20.0			
•3 hp motor	10.0			
•belts(3)	12.0			
•vibration mounts	9.0			
•3 hp motor	10.0			
•bearings(4)	20.0			
•gear reduction(3)	3.0			
•pulley(2)	11.0			
SHREDDER ASSEMBLY	200.2	π = 2.0	400.4	2498
•5 hp motor	28.0			
•coupling	28.0			
•gear reducer	28.0			
•shafts(2)	28.0			
•23 hp motor (2)	20.0			
•bearings	5.0			
•gears(2)	200.0			
•shaft	2.2			
•gear reducer	3.0			
•5 hp motor	11.0			
•bearings(4)	20.0			
•pulleys(2)	11.0			
•belts(2)	80.0			
•15 hp motor	10.0			
•drive	12.5			
•shaft	2.2			
•3/4 hp motor	10.0			
•bearings(2)	10.0			
•gear reduction	3.0			
•pulley	5.5			
•belt	40.0			

APPENDIX A (Continued)

Part Failure Rate Data - NAS Jacksonville HRI

Subsystem	Base $F/10^6$ hrs	Adjustment Factor	Adjusted $F/10^6$ hrs	MTBF
MAGNETIC SEPARATOR	162	π = 1.50	243	4115
•rectifier	55.0			
•5 hp motor	11.0			
•discharge conveyor	28.0			
•belt	40.0			
•conveyor drive	28.0			
AIR CLASSIFICATION	N/A	N/A	N/A	N/A
TROMMEL SCREEN	93.2	π = 2.5	233	4292
PROCESSING TRAIN CONVEYORS	68.0	π = 1.0	68	14706
•storage bin feed conveyor	28.0			
•belt	40.0			
STORAGE BIN DRIVE	139.8	π = 2.00	279.6	3577
•3/4 hp DC motor	10.0			
•25 hp motor	10.0			
•drives(2)	25.0			
•pulleys(2)	11.0			
•coupling(1)	10.6			
•reducer	3.0			
•shaft	2.2			
•storage bin discharge conveyor	28.0			
•belt	40.0			
INCINERATOR FEED CONVEYOR	235.0	π = 1.50	352.5	2922
•5 hp motor	11.0			
•reducer	3.0			
•bearings(4)	20.0			
•pulleys(2)	11.0			
•feed conveyor #2	35.0			
•belts(3)	120.0			

APPENDIX A (Continued)

Part Failure Rate Data - NAS Jacksonville HRI

Subsystem	Base $F/10^6$ hrs	Adjustment Factor	Adjusted $F/10^6$ hrs	MTBF
INCINERATOR #1	442.7	π = 1.50	6664	1506
•solenoid valve(8)	12.8			
•globe valves(8)	120.0			
•PR valves (12)	28.8			
•gate valves(8)	71.6			
•1/3 hp motor(4)	10.0			
•pump(4)	14.0			
•purge timer	63.6			
•7 1/2 hp motor	10.0			
•hydraulic power pack	10.0			
•thermocouple	80.2			
•thermo switch (5)	21.0			
•piping	0.7			
INCINERATOR #2	442.7	π = 1.50	664	1506
INCINERATOR #3	442.7	π = 1.50	664	1506
BOILER ASSEMBLY #1	377.8	π = 1.25	472.2	2118
•gate values(7)	62.6			
•check valve	1.1			
•level control valve	30.0			
•PB switch(2)	1.1			
•boiler tank	268.0			
•1/8 hp motor	10.0			
•piping	5.0			
BOILER ASSEMBLY #2	377.8	π = 1.25	472.2	2118
BOILER ASSEMBLY #3	377.8	π = 1.25	472.2	2118

APPENDIX A (Continued)

Part Failure Rate Data - NAS Jacksonville HRI

Subsystem	Base $F/10^6$ hrs	Adjustment Factors	Adjusted $F/10^6$ hrs	MTBF
ID FAN #1	49.7	π = 2.25	111.8	8943
•axial fan	3.7			
•current relay	20.0			
•3 hp motor	10.0			
•damper	6.0			
•motor	10.0			
ID FAN #2	49.7	π = 2.25	111.8	8943
ID FAN #3	49.7	π = 2.25	111.8	8943
ASH REMOVAL	124.5	π = 2.50	311.2	3213
•3 hp motor	10.0			
•sleeve bearings(2)	10.0			
•gear reducer	3.0			
•drive	40.0			
•pulley	5.5			
•coupling	10.6			
•shafts(2)	0.4			
•float control valve	30.0			
•sump pump	15.0			
BOILER FEED #1	26.0	π = 1.0	26	38462
•20 hp motor	10.0			
•feed pump	0.5			
•valves	8.9			
•D.A. tank	3.0			
•heat exchanger	3.6			
BOILER FEED #2	26.0	π = 1.0	26	38462
•Same as #1				

APPENDIX A (Continued)

Part Failure Rate Data - NAS Jacksonville HRI

Subsystem	Base $F/10^6$ hrs	Adjustment Factor	Adjusted $F/10^6$ hrs	MTBF
MOTOR CONTROL CENTERS 1-6	126.4	$\pi = 1.25$	273.8	3652
•starter motors(14)	210.0			
•PB switches(5)	9.0			

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CA; Code 120C, (Library) San Diego, CA; Code 154, Great Lakes, IL; Code 240, Subic Bay, R.P.; Code 30V, Norfolk, VA; Code 400, Great Lakes, IL; Code 400, Pearl Harbor, HI; Commanding Officer, Guam; Code 505A Oakland, CA; Library, Guam; Library, Norfolk, VA; Library, Oakland, CA; Library, Pearl Harbor, HI; Commanding Officer, Great Lakes, IL; Library, Subic Bay, R.P.; Library, Yokosuka JA; Maint. Control Dept (R. Fujii) Pearl Harbor, HI; Util Dept (R Pascua) Pearl Harbor, HI
SCS ENGINEER Long Beach, CA
SPCC PWO (Code 120) Mechanicsburg PA
SUPANX PWO, Williamsburg VA
AF HQ USAFE/DEE, Ramstein GE
US FORCES, JAPAN Environmental Coordinator Yokota AB; Engr Staff Officer
USDA Forest Products Lab, Madison WI; Forest Service, Bowers, Atlanta, GA
USNA Ch. Mech. Engr. Dept Annapolis MD; ENGRNG Div, PWD, Annapolis MD; Energy-Environ Study Grp, Annapolis, MD; Environ. Prot. R&D Prog. (J. Williams), Annapolis MD; USNA/Sys Eng Dept, Annapolis, MD; PWO Annapolis MD
ALABAMA ENERGY MGT BOARD Montgomery, AL
ARIZONA State Energy Programs Off., Phoenix AZ
CALIFORNIA STATE UNIVERSITY LONG BEACH, CA (CHELAPATI)
COLORADO STATE UNIV., FOOTHILL CAMPUS Fort Collins (Nelson)
DAMES & MOORE LIBRARY LOS ANGELES, CA
HAWAII STATE DEPT OF PLAN. & ECON DEV. Honolulu HI (Tech Info Ctr)
ILLINOIS Pollution Control Bd, Chicago, IL
KEENE STATE COLLEGE Keene NH (Cunningham)
LOUISIANA DIV NATURAL RESOURCES & ENERGY Div Of R&D, Baton Rouge, LA
MAINE OFFICE OF ENERGY RESOURCES Augusta, ME
MISSOURI ENERGY AGENCY Jefferson City MO
MIT Cambridge MA
MONTANA ENERGY OFFICE Anderson, Helena, MT
NATURAL ENERGY LAB Library, Honolulu, HI
NEW HAMPSHIRE Concord NH (Governor's Council on Energy)
NYS EMERGENCY FUEL OFFICE Albany NY (Butler)
NYS ENERGY OFFICE Albany, NY; Library, Albany NY
NYS ENERGY R&D AUTH Albany, NY
PURDUE UNIVERSITY Lafayette, IN (CE Engr. Lib)
SOUTH DAKOTA ENERGY Off of Energy Policy (Wegman) Pierre SD
STATE OF CALIF. Solid Waste Mgmnt Bd Sacramento, CA
STATE UNIV. OF NEW YORK Buffalo, NY
TENNESSEE ENERGY AUTHORITY Nashville, TN
UNIVERSITY OF CALIFORNIA Energy Engineer, Davis CA
UNIVERSITY OF ILLINOIS URBANA, IL (LIBRARY)
UNIVERSITY OF MASSACHUSETTS (Heronemus), ME Dept, Amherst, MA
VENTURA COUNTY PWA (Brownie) Ventura, CA; Plan Div (Francis) Ventura, CA
AUSTRALIA Alno, USA Meradcom Ft. Belvoir, VA
CHEMED CORP Lake Zurich IL (Dearborn Chem. Div.Lib.)
FORD, BACON & DAVIS, INC. New York (Library)
MIDLAND-ROSS CORP. TOLEDO, OH (RINKER)
POTOMAC ENERGY GRU (Naismith) Alexandria, Va
RAYMOND INTERNATIONAL INC. E Colle Soil Tech Dept, Pennsauken, NJ
3 M Technical Library, St. Paul, MN
TEXTRON INC BUFFALO, NY (RESEARCH CENTER LIB.)
UNITED KINGDOM LNO, USA Meradcom, Fort Belvoir, VA
UNITED TECHNOLOGIES Windsor Locks CT (Hamilton Std Div., Library)
WESTINGHOUSE ELECTRIC CORP. Annapolis MD (Oceanic Div Lib, Bryan)
SOCHA Somers, CT
WALTZ Livermore, CA

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